Pergamon

Cement and Concrete Research 30 (2000) 1485–1488

CEMENT AND CONCRETE RESEARCH

Communication

Hydration of bagasse ash-blended portland cement

N.B. Singh*, V.D. Singh, Sarita Rai

Department of Chemistry, DDU Gorakhpur University, Gorakhpur, U.P. 273009, India

Received 1 September 1999; accepted 2 June 2000

Abstract

Hydration of bagasse ash (BA)-blended portland cement has been studied by employing a number of experimental techniques. It is found that in presence of BA setting times are increased and free lime is decreased. The compressive strength values increased with hydration time in the presence of BA and the values were found to be higher than that of control. The blended cement was found to be more resistant in an aggressive environment. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Blended cement; Bagasse; OPC; Compressive strength; Expansion

1. Introduction

Blended cements are used for a number of reasons [1–3]. The necessity for utilizing waste materials and decreasing overall energy consumption is becoming increasingly obvious. Fly ash and blast furnace slags are the major waste materials and concretes made with them can have properties similar to those of ones made with pure portland cements at lower cost per unit volume. Concretes made with blended cements can have properties that are desirable for particular purposes. Apart from these materials, a number of other waste materials such as silica fume [4,5] and rice husk ash [6–9] are also being used extensively as a blending component. Silica fume is a byproduct of the production of silicon or silicon alloys by reducing quartz in an electric furnace and contains 94–98% SiO_2. It has a very high surface area. The silica fume has a strong pozzolanic property and when added to cement, accelerates the reaction of clinker phases, increases the strength and lowers the permeability [4]. The rice husk burned under controlled conditions contain nearly 90% amorphous silica, retaining the cellular microstructure of the original material and has a very high specific surface area. Its possible utilization in conjunction with calcium hydroxide or cement has received attention for reasons of economy and energy conservation, and also because it can be used to make concretes that are resistant to acid attack. Rice husk ash has characteristics similar to those of silica fume but can be more strongly pozzolanic.

Scientists are always in search of waste materials that can be used as a blending component in cements to improve its quality and reduce the cost. Recently, Harilica et al [10] used pressurized fluidized bed combustion ashes formed at relatively low temperatures and elevated pressures as a blending component in portland clinker and found that it increases the early strength development and has high hydraulic and pozzolanic activity. Some other waste materials like bag house dust [11], alkali bypass dust [12], phosphorous furnace slag [13] etc., have also been used as a blending component in cements.

When juice is extracted from the cane sugar, the solid waste material is known as bagasse. When this waste is burned under controlled conditions, it also gives ash having amorphous silica, which has pozzolanic properties. In this paper hydration of bagasse ash (BA)-blended portland cement has been studied and the mechanism discussed.

2. Experimental

2.1. Materials

Ordinary portland cement (OPC) has a Blaine surface area of 4250 cm^2/g and its chemical and mineralogical compositions are given in Tables 1 and 2, respectively. Boiler-fired BA obtained from “The Kanoria Sugar Works,

---

* Corresponding author. Tel.: +91-551-338859.

PII: S0008-8846(00)00324-0

Table 1
Oxide composition of portland cement

Oxide	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	PbO	ZnO	MnO	P_2O_5	SO_3
Composition (wt.%)	19.75	4.84	3.26	62.66	4.19	0.54	0.06	0.44	0.77	0.09	0.15	0.03	2.13

Captainganj, Kushinagar" was used as a blending component and its oxide composition is given in Table 3.

2.2. Blended cements

Blended cements were prepared by mixing OPC with different amounts of BA (10, 20 and 30 wt.%). The mixtures were thoroughly homogenized in polythene bottles.

2.3. Methods

Hydration of OPC and blended cements (W/S=0.5) was stopped at different intervals of time (1, 3, 7, 15 and 28 days) with the help of isopropyl alcohol and ether. The hydrated samples were dried at 105°C and stored in a desiccator in polythene bags.

Free lime contents were determined by modified Franke method and non-evaporable water contents by measuring the weight loss at 1000°C. XRD and DSC on selected hydrated samples were also recorded at Institute fur Gesteinshüttenkunde, Aachen, Germany, and Nagpur University, respectively.

Water consistency, setting time, compressive strength and expansion in sulphuric acid (N/60) were determined in accordance with Indian standard specifications IS:4031, 1988.

Electrical conductivities of the suspensions of OPC and blended cements (W/S=3.0) were measured as a function of time at room temperature (30±2)°C with the help of a conductivity meter (Toshniwal) using conductivity cell.

3. Results and discussion

Water consistency of the blended cements increased with the increase of BA (Table 4). It may be due to the higher surface area of BA as compared to that of OPC. Both initial and final setting times increased with the increase of BA (Table 4). Up to 20% BA, there was a slow increase, but after that the increase was rapid. The results indicate that BA retards the setting; however, the retardation is negligible up to 10% replacement of OPC by BA. This may be due to adsorption of water at the surface of BA (higher surface area). The higher the BA, the higher is the adsorption of water. Thus, the higher amount of water will retard the setting. Further, the reduced amount of OPC in the blended cement may also be responsible for retardation of setting.

The electrical conductivity values of suspensions of OPC and 10% BA blended OPC (W/S=3.0) were measured with hydration time (up to 150 min). As soon as OPC comes in contact with water, there is a rapid increase in electrical conductivity value.

This is due to the dissolution of cement constituents in water. As the number of conducting ions in solution increases, there is an increase in conductivity value. The variation of electrical conductivity of the blended cement follows a similar trend, but the values are always lower than that of control. The lower values may be due to the dilution effect or the retardation effect of BA.

The non-evaporable water content (Wn) in the presence and absence of 10% BA was measured. In the presence of 10%BA, Wn values are higher up to 3 days of hydration, and after that the values are lower up to 28 days of hydration as compared to that of the control. The higher values during the early days of hydration in the presence of BA may be due to the unburned carbon present in BA. The lower values indicate the lower extent of hydration in the presence of BA. This may be due to a dilution effect. Free lime values were also determined. In the case of control, the free lime increased with hydration time, indicating an increase of hydration. In the presence of BA the values are always lower than that of the control up to 20% BA. The free lime values increased up to 3 days and then there was a decrease. These results clearly indicate that BA acts as a pozzolanic material and the decrease in free lime values is due to pozzolanic reaction. The higher the amount of BA, the higher is the pozzolanic activity.

DSC curves of OPC and blended cement show endotherms at 120°C due to the decomposition of calcium silicate hydrate and the enthalpy values for OPC and blended cement are 13.8 and 25.2 J/g, respectively. These values clearly indicate that higher amounts of calcium silicate hydrates are formed in the presence of BA.

The second endotherm at around 485°C is due to the decomposition of calcium hydroxide formed during the course of hydration. Again, the amount of calcium hydroxide formed is less in the presence of BA as compared to

Table 2
Mineralogical composition of portland cement

Phase	C_3S	C_2S	C_3A	C_4AF
Composition (%)	67.8	5.51	7.31	9.92

Table 3
Oxide composition of BA

Oxide	LOI[a]	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	SO_3
Composition (%)	6.90	63.16	8.40	9.70	5.40	2.90	2.87

[a] LOI is mostly due to unburnt carbon.

Table 4
Water consistency, initial and final setting times

Composition	Water consistency	IST (min)	FST (min)
Control	0.310	105	215
90% OPC + 10% BA	0.324	128	225
80% OPC + 20% BA	0.384	240	345
70% OPC + 30% BA	0.460	821	1080

Temperature = 32 ± 2°C.

that of control. The lower values of calcium hydroxide in the presence of BA may be either due to the dilution effect or due to the pozzolanic reactions of BA. These results have been supported by XRD patterns.

The variation of compressive strength with BA and time is shown in Fig. 1. The compressive strength in the case of control increased with hydration time. In the presence of 10% BA, the values also increased with time and were always higher than that of control. However, at higher addition of BA (>10%), the values were lower and much lower at 28 days of hydration. Thus, 10% addition of BA to OPC may be considered as the optimum limit. The increase in compressive strength in the presence of 10% BA may be both due to physical and chemical processes. BA is fine powder with high specific surface area and in cement paste it may lead to the segmentation of large capillary pores. It may also introduce a large number of nucleation sites in the system for the rapid precipitation of hydration products. Further, the pozzolanic reaction between calcium hydroxide and silica and the hydration of silica itself in the alkaline environment will be responsible for the increased compressive strength. In presence of 10% BA the percent increase (compared to control) in compressive strength is shown in Fig. 2.

The influence of 10% BA in reducing the chemical deterioration of cement mould on exposure to N/60 H_2SO_4 was measured as a function of hydration time. The percent expansion was measured. In the case of control, it increased with time but in the presence of 10% BA there is a slow increase in expansion and the values are much lower than that in the case of control. The improved acid resistance of the blended cement mould containing BA may be due to the pozzolanic reaction of calcium hydroxide, which is readily attacked by H_2SO_4. It is also possible that BA reduces the permeability.

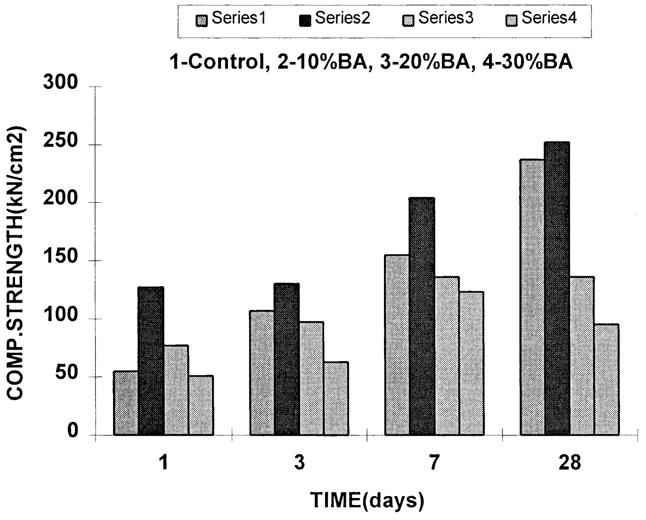

Fig. 1. Variation of compressive strength with curing time.

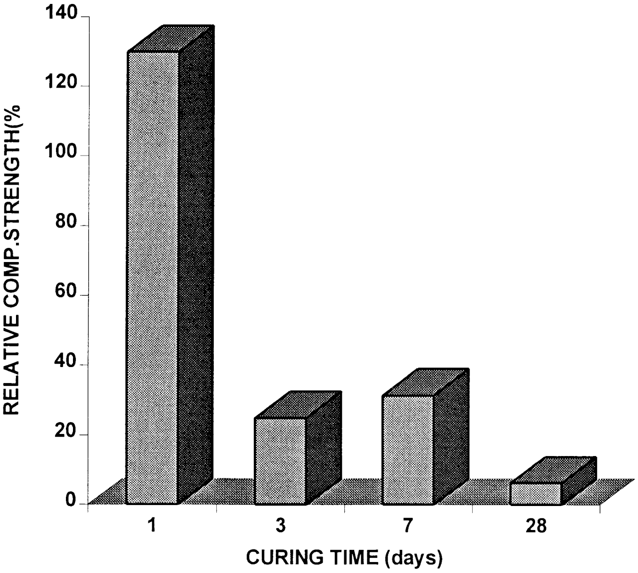

Fig. 2. Relative increase in compressive strength in the presence of 10% BA.

4. Conclusions

The overall results indicate that BA acts as a pozzolanic material, and in its presence the extent of hydration is lower as compared to that of control. However, in the presence of 10% BA the compressive strength values were found to be higher than that of control at all ages of hydration. The chemical deterioration of blended cement mould in the presence of N/60 H_2SO_4 is lower as compared to that of control. This is due to the pozzolanic reaction of BA and also the reduction in permeability in its presence.

Acknowledgments

The authors are thankful to UGC, New Delhi for financial assistance.

References

[1] H. Uchikawa, Effect of blending components on the hydration and structure formation, Proc 8th Int Cong Chem Cem, Rio de Janeiro 2 (1986) 250.

[2] H.F.W. Taylor, Cement Chemistry, 2nd ed., Thoma Telford, 1997.

[3] D.J. Cook, P. Juwanvitaya, Fly ash, silica fume, slag and other mineral by products in concrete, in: V.M. Malhotra (Ed.), Am Concr Inst, SP 79 vol. 2, American Concrete Institute, Detroit, MI, 1983, p. 831.

[4] N.S. Berke, M.P. Dallaere, M.C. Hicks, Plastic, mechanical corrosion and chemical resistance properties of silica fumes, Am Concr Inst, SP 132 (1992) 11255.

[5] G.G. Carette, V.M. Malhotra, Mechanical properties, durability and drying shrinkage of portland cement concrete incorporating silica fume, Cem Concr Aggregates 5 (1) (1983) 3.

[6] J. James, M.S. Rao, Reactivity of rice husk, Cem Concr Res 16 (1986) 296.

[7] P.K. Mehta, Advances in Concrete Technology, in: V.M. Malhotra (Ed.), Energy, Mines and Resources, Ottawa, Canada, MSL 92-6 (R), 1992, p. 1.

[8] N.B. Singh, R. Sarvahi, S.P. Singh, A.K. Shukla, Hydration of studies of rice husk ash as blended white portland cement, Adv Cem Res 6 (1994) 13.

[9] N.B. Singh, R. Sarvahi, A.K. Shukla, Rice husk blended portland cement, Silic Ind LX (3–4) (1995) 83.

[10] J. Harilica, J. Brandstet, I. Odler, Possibilities of utilizing solid residues from pressured fluidized bed coal combustion (PSBC) for the production of blended cements, Cem Concr Res 28 (1998) 299.

[11] N.B. Singh, K.N. Bhattacharjee, A.K. Shukla, Hydration studies of non portland blended cements made from bag house dust of calcium carbide furnace, Trans Indian Ceram Soc 54 (1995) 52.

[12] N.B. Singh, K.N. Bhattacharjee, A.K. Shukla, Effect of alkali by pass dust on the hydration of granulated blast furnace blended cement, Cem Concr Res 25 (1995) 883.

[13] N.B. Singh, K.N. Bhattacharjee, A.K. Shukla, Hydration of phosphorous furnace slag blended cements, Cements 92 (1995) 253.